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HIGH BUILDINGS AND EARTHQUAKES.

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IT IS evident that the advance of our architecture is rapidly making the conditions of its earth foundation a matter of increased importance. In the earlier and simpler state of our edifices they were of relatively slight height and with such reserves of strength as would enable them to withstand a considerable movement of their foundations. The need of room and the desire for display have of late led us to construct tower-like buildings which are much more dependent for their safety on a firm set earth. The development of elevators greatly favors this change in the type of our houses. It is indeed likely that we are hereafter to see a perpendicular type of architecture wherein the roofs of ordinary city buildings will attain a height to which of old only the more ambitious architects lifted their steeples.

Although architects in general are exceedingly careful in securing the foundations of their buildings against the chance of mishap, they, like other people, are disposed to regard the earth as firm set. They rarely, even in countries where serious earthquake shocks are to be anticipated, take any measures to provide against the calamities which these movements entail. Except in Japan, where long and bitter experience has taught the people to build with reference to seismic disturbances, no general precautions directed to this end have ever been taken. The only builders who have ever read the earthquake lesson aright are those of California, where in many cases admirable precautions have been taken to insure the greater edifices against the dangers which earth tremors may bring to them. We have now to discuss the question whether the architects who are shaping our great cities of the Mississippi Valley and of the Atlantic seaboard may not do well to follow the example of their brethren on the Pacific coast. To determine this question we must first consider the evidence as to the danger which is to be apprehended from earthquake disturbances in those parts of our continent.

The written history of North America is obviously insufficient in length to give us any clear idea as to the liability of the continent as a whole to earthquake disturbances. No part of this record goes back as much as four centuries, and for the greater part of the land we know of these happenings for only about a hundred and fifty years. The untrustworthiness of this information is indicated by the fact that if we knew the seismic history of Europe and Asia only for the time during which we know that of North America, the story which has been written would be altogether different from that which the records afford. In the lack of human records we have to avail ourselves of the evidence which may be drawn from the physical state of the surface in these districts. This, though less complete and clear than ordinary chronicles, is not without value to the architect as well as the geologist, and may be interesting to the general reader.

Wherever in any country we find portions of the surface materials in a state of unstable equilibrium which would be disturbed by a considerable shaking of the ground, we may safely presume that the region has not been dislocated by a violent shock for the period during which these conditions have prevailed. Thus, where there are slender and delicately poised natural obelisks of rock formed along the faces of cliffs by the process of erosion, we may know that their foundations have been undisturbed for hundreds of years by any violent earth movement; where, also, steeply sloping masses of detritus lie at the base of cliffs we may be often sure that no earth-shaking has occurred for a period which in the terms of human history must be estimated as long. Owing to the novelty of this method of inquiry the present writer has only been able to make imperfect application of it in the fields we are considering, but the evidence indicates pretty clearly that the region of the Great Lakes, the part of the Ohio Valley lying to the east of the meridian of Louisville, the whole of the Appalachian Highlands, and the region of New England, including the district about the Gulf of St. Lawrence, has for a period of some thousand years been exempt from the more violent class of earthquake accidents such as are likely to ruin buildings constructed with a reasonable measure of precaution against a movement of their foundations. We may therefore conclude that in the districts described we may with due care reckon on meeting the hazards of this nature which are likely to arise.

Although the physical account of earthquakes which is afforded by the evidence above described indicates a tolerable immunity from violent earthquakes in the central and eastern portions of the United States, the written history of this region shows us that we may expect seismic disorders in several parts of the field. The earthquake of 1811, which had its centre of action in the region just south of the junction of the Ohio and Mississippi rivers, was a disturbance which from its intensity and continuity has rarely been equalled in any part of the world. For a month or more the violence of the shocks was such as to break up the timber huts of the pioneers, though those buildings were of a type admirably suited to withstand strains of this description. The recurrence of this disturbance in the region, some twenty thousand square miles in area, where the shocks were most violent would probably ruin any building which it is worth while to construct. There are, fortunately, reasons, which cannot be discussed here, for believing that the visitation of the New Madrid earthquake was of a very exceptional nature, and that another such accident had not occurred in the field where it happened for many thousand years.

Along the Atlantic seaboard, brief as are the historic accounts of this district, we find two considerable fields which are evidently liable to repeated seismic visitations of moderate intensity. One of these includes the greater part of New England and the portion of the St. Lawrence Valley now known as the Province of Quebec. The other field may be described as the Carolinian, with its centre near Charleston. In the first mentioned of these areas there have been three shocks of noteworthy importance since the country was settled by Europeans. The first of these occurred in 1685 ; the second, a long continued period of disturbance affecting a small region about the mouth of the Merrimac, from 1727 to 1740 ; and the third, a widespread and strong quaking which came in 1755. The records show clearly that all these disturbances involved a sufficient amount of movement to have proved very destructive to the buildings of our time. That of 1755 recurring in the Boston of to-day would inevitably lead to a vast loss of life and property. Such was the violence of the movement that bricks were thrown from the top of a chimney thirty-two feet high, striking the ground at thirty feet from its base. The Boston of that day was mainly built of timber, and the masonry constructions were low and strong. There was therefore no loss of life and little of property, except from the overthrowing of many hundred chimneys. Prof. John Winthrop, then Hollisan Professor in Harvard College, in his lecture on this earthquake, preserved to us in a rare pamphlet which really began the science of seismology, states that during the worst of the shock it was difficult for a person to keep his feet. Since this great shaking the New England area has been exempt from menacing disturbances, but the frequency with which the minor shocks have occurred shows very clearly that the area is liable to disturbances which may, at any time, regain the violence which characterized them in the preceding century.

The Carolinian area, though the seat of no noteworthy shocks during the colonial period of its people, has during the present century experienced two considerable shakings. It shared in the disturbances which radiated from the New Madrid district in 1811–13, but these movements did not attain to destructive violence. The shock of August, 1886, originated in this field, and though only of moderate severity, probably not as great as that of 1755 in New England, did a great deal of damage to life and property. In both these regards it was the most destructive earthquake ever known in the portion of the continent lying to the north of Mexico. Nevertheless the damage which was done was altogether of an evitable nature; a proper care in the construction of the edifices which were overthrown would have insured them from any considerable damage, and it is very unlikely that any lives were lost save through the imperfections in the structures which suffered from the earth movement. This is well shown by the fact that the lighthouses of this district, some of which experienced a test essentially similar to that which was brought upon the buildings in the town of Charleston, escaped without material injury. In fact the damage done in that city appears to have been almost altogether due to thin walls and poor mortar, along with errors in plan which made the buildings ill-fitted to withstand any movement of their foundations.

The occurrence of four earthquake shocks of importance in the last three hundred years in the region along the Atlantic coast makes it evident that from the point of view of the architect who would build in an enduring way, in a manner to insure safety, even in improbable contingencies, to those who dwell under his roof trees, this region is to be reckoned as anything but firm-set earth. The measure of responsibility which rests upon those who control our constructions in this part of the United States may fairly be deemed grave. It is true that the probability of a great shock affecting the more important cities of the Atlantic coast in any one year is very small, but the likelihood of such a disturbance occurring during the lifetime of any well-constructed masonry edifice is clearly great.

Although the portion of our Atlantic shoreland which contains the greatest number and the largest cities of the coast, that stretched between the James River and Narragansett Bay, has since its settlement at no time been rudely shaken, there seems no reason to believe that it is in a large way less liable to disturbance than the areas which lie on its borders. At any time the tensions of the deeper earth which give rise to earthquake shocks may accumulate to a point where they have to be discharged by a movement of the rocks. The physical evidence, gathered from the conditions of the surface, would seem to indicate that the quaking likely to result from such a crisis will be no more severe than those which are recorded in New England and South Carolina, but it may be sufficient sorely to test all large constructions which have not been built with reference to it.

Assuming that our architects should reckon with the possibilities of earthquake shocks the question arises, what kind of precautions it may be necessary to take in order to avoid the dangers which such movements entail. Fortunately for our inquiry the studies of seismologists enable us to give a tolerably clear and sufficient answer to these questions. To understand the conditions, it is necessary in the first place to note the fact that an earthquake shock is in its essential features a vibration like that which is induced in a bell or tuning fork in consequence of a blow. It is not a single movement, but a series of oscillations, of which the first is the strongest, and each in the succession is proportionally less in violence. There may be, and indeed there commonly is, a succession of these blows, extending over a period of days or weeks in duration, with intervening periods of quiet. In the region which we are considering, the amplitude of the movement in each vibration is not likely to exceed an inch or two, and each swaying takes place in a rapid manner occupying perhaps less than a second of time. We should now note the fact that earth movements are not sufficient to rend well-bound masonry asunder, except under conditions which put peculiar and unnecessary strains upon it. Even very tall structures cemented with good mortar, though they have the height of the Washington Monument, are not likely to be damaged by convulsions such as have occurred along the Atlantic coast within the historic period. The fact is that all our masonry materials, brick as well as stone, are very elastic. The reader may assure himself of this fact by throwing a boy's marble, of the species which is really composed of marble rock, upon a floor of similar material. He will at once observe that the little sphere rebounds unharmed, and with something like the spring which is characteristic of India rubber. Such marbles can readily be made to leap to the height of twenty or thirty feet without breaking. Thus it comes about that well-bound masonry can, under favorable conditions, withstand a very severe oscillating strain, the shocks being taken up by the easy and not harmful vibrations of the mass.

The danger arising from earthquakes is greatly increased wherever there is a large amount of weight in the form of masonry cornices or other decorations carried to a considerable height above the ground. The energy with which these heavy portions of the building move tends to tear them free from the subjacent masonry and from the fastenings with which they are readily retained so long as the only disturbing force is gravitation. Walls which would withstand the whip of an earthquake shock are very likely to be broken by the intense stress which comes upon them from such a weight as is often found in these unnecessary ornaments. The same objection in even greater measure applies to those structures where an upper story of heavy materials is carried on slender columns or piers of masonry. Thus many ornamental towers have above their bell-deck a considerable crown of stonework, which sometimes rises in the form of a lofty spire. Buildings so planned invite destruction from earthquakes. The vibration which is readily transmitted by the solid portions of the tower cannot be carried through the piers of the open story to the massive superstructure. The inertia of the overlying mass makes it certain that the two sections of the column cannot move in unison, and a rupture necessarily takes place.

The modern plan of having the floors of our greater buildings composed of masonry held on iron girders has, from the point of view of the seismologist the disadvantage that it accumulates a great deal of weight at certain levels in high buildings and necessarily leads to violent thrusts upon the walls during the period of a shock. Where the seat of the disturbance which creates the earthquake is anywhere near vertically below such massive floored buildings, the inevitable tendency is to crush down the supports of these partitions and to carry the mass in commingled ruin to the ground floor. These vertically moving earthquake waves, however, commonly occupy only a small portion of the field which is affected by the movement; so this peculiar danger may perhaps be neglected.

Buildings situated in the close-set order in which they are found in the solid blocks of our great cities are much less likely to suffer from moderately violent earthquakes than are the detached edifices of like mass and height which occupy open spaces. In the serried order of the ordinary streets the structures give each other such mutual support that walls and floors may hold their position where they would otherwise be overthrown. Much also depends upon the general style of the architecture. The Gothic form, which more than any other involves a trust in the stability of the earth—with the undivided height of its internal spaces, with its great mass of masonry decoration carried far above the earth—is least fitted to withstand earthquake shocks. It is perhaps on this account that structures of this model are rarely if ever found in those portions of Europe which are subject to these visitations. The architecture which prevailed in Greece, and that which was developed in Rome, is, on the whole, better suited to afford security during earth movements than that which has taken shape in the firmer-set lands of central and northern Europe. The Romans knew particularly well how to combine dignity and ornament in construction with the strength which was necessary in buildings erected in the earthquake-ridden portion of Italy. Above all, they knew how to bind stones or brick together with good mortar, which is the first important element in guarding against such accidents as we are now considering.

It seems not improbable that a high measure of security may soon be attained against the ravages of earthquakes through the increasing use of iron or rather low grade steel in the builders' art. An edifice framed of this metal, provided proper precautions were taken to tie the mass firmly together on vertical and horizontal lines, should be much more completely proof against dislocating movements than any masonry structure whatsoever. It would be possible to construct a building of this material which would defy any movement of a seismic nature except those infrequent accidents of certain rare lands where the shocks have been so furious as utterly to devastate the surface of the earth. Any very general use of steel in great buildings is apt to come about slowly. Doubtless, for a long time our architects will have to reckon with the qualities of masonry and with constructions of stone or brick.

It must not be supposed that the measure of danger which is to be apprehended from earthquake shocks in the eastern half of the United States is sufficient to justify any general change in our methods of building. The risk, however, is clearly such as makes it fit for the architect to consider how, with little departure from the paths of evident and immediate need, he may guard against the dangers which such accidents entail. If he will but bear in mind the nature of the strains which arise from the quakings to which his foundations may be subjected, he may in most cases, without greatly increasing the cost of his work, so plan and construct it as to insure its occupants and owners from danger to life and property. It seems not unreasonable to ask this care of him, for he, more than any other of the orders of society, has the wealth and welfare of the people in his keeping. If he be fully informed by the noble motives of his craft, he is already accustomed to face the contingencies of the centuries to come at the time when he makes ready for his construction. He computes not only for the resistance which is necessary in order to meet the strains brought about by ordinary winds, but for the strength which is required to resist those storms which come but once in a hundred years. It will add but little to the scope of his reckoning to take account of the accidents arising from the instability of the nether earth.

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